MODAL ANALYSIS AND MODEL CORRELATION OF THE MIR SPACE STATION

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This paper will discuss on-orbit dynamic tests, modal analysis, and model refinement studies performed as part of the Mir Structural Dynamics Experiment (MiSDE). Mir is the Russian permanently manned Space Station whose construction first started in 1986. The MiSDE was sponsored by the NASA International Space Station (ISS) Phase 1 Office and was part of the Shuttle-Mir Risk Mitigation Experiment (RME). One of the main objectives for MiSDE is to demonstrate the feasibility of performing on-orbit modal testing on large space structures to extract modal parameters that will be used to correlate mathematical models.

The experiment was performed over a one-year span on the Mir-alone and Mir with a Shuttle docked. A total of 45 test sessions were performed including: Shuttle and Mir thruster firings, Shuttle-Mir and Progress-Mir dockings, crew exercise and pushoffs, and ambient noise during night-to-day and day-to-night orbital transitions. Test data were recorded with a variety of existing and new instrumentation systems that included: the MiSDE Mir Auxiliary Sensor Unit (MASU), the Space Acceleration Measurement System (SAMS), the Russian Mir Structural Dynamic Measurement System (SDMS), the Mir and Shuttle Inertial Measurement Units (IMUs), and the Shuttle payload bay video cameras.

Modal analysis was performed on the collected test data to extract modal parameters, i.e. frequencies, damping factors, and mode shapes. A special time-domain modal identification procedure was used on free-decay structural responses. The results from this study show that modal testing and analysis of large space structures is feasible within operational constraints.

Model refinements were performed on both the Mir alone and the Shuttle-Mir mated configurations. The design sensitivity approach was used for refinement, which adjusts structural properties in order to match analytical and test modal parameters. To verify the refinement results, the analytical responses calculated using original and refined math models were compared with the measured responses. The results from this study show that the refined models predict more accurately the dynamics of the actual structure.

The MiSDE test and analysis results provided the information and experience on test design, flight testing, and data analysis for the ISS and other future spacecraft, which are critical to the verification of analytical models and structural loads.